

IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear

Sponsor
**Switchgear Committee
of the
IEEE Power Engineering Society**

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Foreword

(This Foreword is not a part of Draft ANSI/IEEE C37.24-1986, IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear.)

This guide originated as a technical paper at the AIEE Winter general meeting in New York, NY, Jan 18–22, 1954. In October 1955, it was issued by AIEE Standards Committee as Publication 955. Subsequent document revision in 1962 included a 3000 A ratings and updating of the temperature data from the National Oceanic and Atmospheric Administration.

This revision of the guide reflects the references to the new standards, ANSI/IEEE C37.20.1-1987, C37.20.2-1987, and C37.20.3-1987 as well as the most recent monthly normal maximum temperatures of the United States; and Canada (1951–1980). A new section, 7, has been written that discusses color and finish of the metal-enclosed switchgear and their impact on temperature due to solar radiation.

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1. Introduction and References

1.1 Introduction

Outdoor metal-enclosed low-voltage power circuit breaker switchgear, outdoor metal-clad switchgear, and outdoor metal-enclosed interrupter switchgear have reached a position of widespread application comparable to that of indoor switchgear. Outdoor switchgear has had a satisfactory operating record for many years in cold, temperate, and hot climates that has contributed to this increased usage. However, there are conditions affecting its application that are different from those for indoor switchgear and warrant special consideration.

This was realized and a study of the situation for metal-enclosed switchgear was undertaken by the Switchgear Assemblies Subcommittee. It was first determined that temperature data were not available on fully loaded units in the field. Outdoor laboratory and field testing was then tried, and it became evident, due to uncontrollable conditions, that accurate and complete data suitable for establishing the current-carrying capability of outdoor metal-enclosed switchgear could not be obtained. Next, indoor testing simulating outdoor conditions was resorted to. Further valuable data were accumulated, but there was still no absolute relationship between results obtained indoors and conditions existing outdoors. However, based on these investigations, sufficient data are now available for the preparation of a guide for using outdoor metal-enclosed switchgear in various climates.

1.2 References

The following publications shall be used in conjunction with this standard:

- [1] ANSI/IEEE C37.20.1-1987, IEEE Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear.¹
- [2] ANSI/IEEE C37.20.2-1987, IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear.
- [3] ANSI/IEEE C37.20.3-1987, IEEE Standard for Metal-Enclosed Interrupter Switchgear.

¹ANSI/IEEE publications can be obtained from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the Service Center, Institute of Electrical and Electronics Engineers, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.

2. Scope

The general information in this guide is applicable to all forms of outdoor metal-enclosed switchgear. Specific data are given in Fig 2 for outdoor metal-enclosed low-voltage power circuit breaker switchgear, outdoor metal-clad switchgear, and outdoor metal-enclosed interrupter switchgear.

3. Purpose

Switchgear will perform satisfactorily and have a reasonable life when operated within the temperature limits established in ANSI/IEEE C37.20.1-1987 [1],² C37.20.2-1987 [2], and C37.20.3-1987 [3]. In outdoor applications, the limiting temperatures result from the net effect of internal losses and external influences, principally the sun, wind, and local ambient temperatures. All of these must be considered in determining the current-carrying capacity of outdoor metal-enclosed switchgear.

ANSI/IEEE C37.20.1-1987 [1], C37.20.2-1987 [2], and C37.20.3-1987 [3] specify the temperature rise above a standard ambient temperature of 40 °C. This is satisfactory for indoor applications where the temperature rise is due entirely to heat release. However, when the gear is located outdoors, several additional factors require consideration. The effect of sun, wind, ventilation, ambient temperature, etc, on internal temperatures will be considered in this guide.

The magnitude of these factors will vary geographically and from season to season. The time relationship of maximum circuit loads with respect to maximum ambient temperature is important. It is not practical to design switchgear on the basis that all adverse factors reach their maxima coincident with maximum loads. If this does not occur, full current ratings may be realized. Recommendations will be made to point out the cumulative effect of these various influences.

4. Operating Limitations

Temperature limitations for metal-enclosed switchgear are established at a value that will ensure satisfactory life of the insulation. Operation at higher temperatures than permitted by the appropriate standard will result in shortened life, but if the temperature of the insulation goes above normal for a few hours during a few days of the year, the effect on total life is hardly measurable. This is very different from the establishment of higher short-duration ratings that might be repetitive on a day-to-day basis. The hazard of immediate breakdown is not increased unless extreme temperatures are reached.

Outdoor metal-enclosed switchgear is usually designed with more restricted ventilation than indoor switchgear with the object of excluding wind-blown dust and dirt. The effect of this is a tendency toward somewhat increased internal temperatures of outdoor switchgear compared to indoor installations with equivalent circuit breakers and buses. These conditions have been recognized in designs. With this restricted ventilation, the effect of solar radiation on an enclosure will cause the air immediately under the roof to be relatively warm. Electrical parts, therefore, located near the roof will be operated in air considerably warmer than that surrounding equipment in the center or lower portion of the switchgear units. Cable insulation of certain types cannot be operated in as high air temperatures as others. If cables are located in the upper part of housings, insulation with appropriate thermal characteristics should be selected. ANSI/IEEE C37.20.1-1987 [1], C37.20.2-1987 [2], and C37.20.3-1987 [3] state in effect that the temperature of the air surrounding outgoing insulated cables in any compartment shall not exceed 65 °C with a maximum average ambient temperature of 40 °C outside the structure based on the use of 90 °C insulated power cables. Use of lower temperature rated cables requires special consideration. In many cases the effect of solar radiation alone will raise the

²The numbers in square brackets correspond to those of the references listed in 1.2 of this standard; when preceded by a "B," they correspond to those documents listed in Section 11., Bibliography.

inside temperature above that permitted by the appropriate standard. The insulation and size of conductors in this location should be carefully considered by both manufacturers and users.

End units, particularly those exposed to the sun during periods of heavy load, should be considered on a different basis from the others in determining loading, conductor sizes, and cable insulation.

In addition to the effect on insulation, high internal air temperatures will increase the total temperature of the conducting parts. If circuit breakers are properly maintained, no adverse effects will result if their temperatures exceed allowable limits by a few degrees for short intervals during a few days of the year. All primary connections in metal-enclosed switchgear are silver surfaced, or the equivalent, and no trouble should be experienced with them if rated temperatures are exceeded under similar conditions. Here again it is important to realize the difference between increased temperatures due to outside influences that occur infrequently as compared to higher short-duration ratings that might be repetitive on a daily basis.

Caution must be used, however, in the application of temperature sensitive devices, such as devices with solid-state components, in outdoor metal-enclosed switchgear. Accelerated component aging and device failure can result from increased temperatures that occur infrequently. Maximum temperature limitations for temperature-sensitive devices should be determined, and those temperature limitations should be considered during equipment design.

5. External Influences on Internal Operating Temperatures

5.1 Ambient Temperatures

The ambient temperature surrounding switchgear is the base to which the temperature rise of insulation and electric parts is added. At rated current, the conducting parts have an established temperature rise above the outside air. If the temperature of this air is lower, the total temperature of the electric parts will be correspondingly reduced. In all test work, measurements are made with the ambient temperatures determined by the methods established in ANSI/IEEE C37.20.1-1987 [1], C37.20.2-1987 [2], and C37.20.3-1987 [3], and the thermal performance of the equipment is based on the temperature rise above these ambient temperatures. Outdoor ambient temperatures vary widely in most localities over a 24 h period and provide a varying influence on the internal temperatures of switchgear. Under the more stable conditions affecting indoor applications, it is possible to establish a reasonably accurate relationship between ambient temperatures and the temperature rise of electrical equipment. However, with the changing conditions that exist outdoors, it was found that it was impossible to get test data sufficiently accurate and consistent for use in establishing the current-carrying capability of switchgear. The establishment of ambient temperatures over a considerable period of time, as would be necessary to fix a value to be used for determining the loading of switchgear, is a rather lengthy procedure. Readings of ambient temperature should be taken in standard US Weather Bureau enclosures. The construction of these can be obtained from any US Weather Bureau Station. The housing for the thermometer should be located in a position that will expose it to air of about the same temperature as that around the switchgear. In outdoor locations there is no significant variation with respect to the top, middle, or bottom of the structure. However, the thermometer should not be affected by heat reflection from the ground.

The US Weather Bureau, in [B16], covers data taken or adjusted to a standard time period of 30 years from 1951 to 1980, inclusive. These data were obtained from Weather Bureau Stations in the United States, Hawaii, Alaska, the West Indies, and Pacific Islands and are believed to be the best information available for determining reference temperatures for the purpose of this guide (see Table 3). The monthly normal maximum temperatures are given for each month of the year. The monthly normal maximum temperature for the month of July, for example, is computed by adding the maximum temperature for each day in July in a particular year and dividing the sum by the number of days. This provides the monthly normal maximum temperature for July of that year. The yearly temperatures for that month are averaged to provide the figure shown in the tabulation. It is recognized that an average obtained in this way may be lower than an average based on some particular shorter period of time. Table 4 provides monthly normal maximum temperatures for Canada.

The absolute maximum temperature for a particular month (available in other US Weather Bureau records), is the maximum temperature that has ever been reached in a particular locality. Ordinarily such extremes of temperature would occur for only a few hours on one day over a period of several years. It does not seem feasible to design and apply switchgear on this basis and, therefore, the monthly normal maximum temperatures are recommended for determining the continuous current-carrying capacity of outdoor metal-enclosed switchgear in the locality where it is to be installed and operated. An examination of this tabulation will show that in the hot months of the year the 40 °C (104 °F) standard ambient temperature was exceeded only in Arizona, California, and Nevada. In most localities the monthly normal maximum temperature is considerably below 40 °C (104 °F), leaving a margin that should help to offset some of the adverse factors caused by higher temperature and that should provide longer than normal insulation life.

There are many Weather Bureau Stations where long-time records of those monthly normal maximum temperatures are available in addition to those listed in this guide. Where such additional local Weather Bureau data can be obtained, a check should be made to be sure that the temperature data used for determining current-carrying capacity are representative of the conditions where the outdoor metal-enclosed switchgear will be installed and operated.

5.2 Solar Radiation

The most important source of heat in outdoor metal-enclosed switchgear, aside from electrical losses within the gear itself, is the effect of solar radiation. The intensity (flux density) of solar radiation on a surface normal to the sun's rays, beyond the earth's atmosphere, and at the mean earth-sun distance is termed the *solar constant*. Its value approximates 124 W/ft² (1334 W/m²). In passing through the earth's atmosphere, the sun's radiation is scattered and absorbed by dust, gas molecules, ozone, and water vapor. The extent of this depletion at any given time depends upon the composition of the atmosphere and the length of the path through the atmosphere that the sun's rays must travel. Thus, the irradiance at a given point on the earth's surface depends on this depletion as well as on the deviation from the mean earth-sun distance, the declination of the earth's axis, the time of year, the time of day, and the latitude of the given point.

For example, records at Santa Fe, New Mexico, and Mt Whitney, California, representative of high and dry locations where depletion should be minimal, show magnitudes of 106 and 111 W/ft², respectively. Tests made during the last two weeks of June at State College, Pennsylvania, and at Columbus, Ohio, indicate that a maximum of approximately 97 W/ft² is reached at these two locations. The value varies from zero at sunrise approximately sinusoidally to a maximum at noon (solar time), and diminishes to zero at sunset. Figure 1 shows the measured maximum, irradiation at these two locations and also a curve indicating what this irradiation would be if the increase and decrease during the day were exactly sinusoidal. The average irradiation at both locations was considerably below the maximum values shown in Fig 1. However, in other localities, particularly in the West, full values of irradiation may be an almost daily occurrence in the summer.

A value of 97 W/ft² was chosen as a practical value representative of areas in which the majority of outdoor metal-enclosed switchgear will be installed. Indoor tests were made with this value of irradiation simulated by banks of infrared lamps. These lamps were selected from a practical standpoint, but they are not entirely satisfactory since their emission does not contain the entire spectrum of solar radiation. The indoor tests did take into account the additional horizontal component of irradiation on a southern-exposed vertical surface, which approximated 29 W/ft² at 40 ° north latitude at the time of the field measurements.

On the basis of field measurements, indoor tests, and calculated data that were accumulated during this study on outdoor metal-enclosed switchgear, it was established that the maximum temperature rise of the conducting parts due to solar radiation alone is about 15 °C (27 °F).

5.3 Wind Influence

It is estimated that a 10 mi/h (4.5 m/s) wind would totally offset the heating effect of the noonday sun. However, switchgear structures vary so much in shape and relative amount of exposed surface that no accurate figure can be